An Experimental Investigation into the Grindability Aspects of Newly Developed Ceramic Composite (AlSiTi)

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Abstract: - **Ceramics are getting widely used in many engineering applications. These ceramic materials need to be ground. Unfortunately, the ground ceramic components mostly contain surface/subsurface damages. To minimize the grinding induced damages selection of appropriate grinding process parameters is very important. Ceramic composite material (AlSiTi) has been selected in the present study to investigate its grindability. This research work deals with the analysis of the process parameters such as wheel speed, table feed and infeed as influential factors, on the force components, grinding specific energy and surface roughness values based on Taguchi's experimental design method. Scanning electron microscopy (SEM) has been used to analyze the subsurface damages. The result provides valuable insight into the grindability aspects of the composite ceramic (AlSiTi).**

Keywords - **Composite ceramic (AlSiTi), Subsurface damage, Taguchi method.**

I. INTRODUCTION

Grinding is widely used as an efficient and effective technique for a finishing process of ceramic materials. Advanced ceramics are in demand for various applications, especially for the automotive, aerospace industries due to their outstanding high-temperature capacity, high hardness, wear resistance, chemical resistance, and lower weight-to-strength ratio compared to engineering alloys and metals. However it is difficult to achieve crack-free surfaces by grinding because of their high brittleness. The brittleness of the ceramic material makes it extremely vulnerable to microcracks formation during the grinding process. Because of hard and brittle nature of a ceramic material, ground workpieces are often left with such damages as cracks, pulverization layers and limited amount of plastic deformation [1]. Such formation of surface/subsurface defects may affect the strength and fatigue life of ceramic components because the surface/subsurface defects act as weak spots for easy crack propagation, thereby accelerating the fatigue failure of the ceramic components in service. So efficient grinding of ceramics is essential for its effective use in industries.Present research focuses on the grindability aspect of newly developed ceramic composite material (AlSiTi). Ceramiccomposite (AlSiTi) have been developed by Industrial Ceramics Technology. The composition of this composite material is 30.9 vol% SiC whiskers, 23 vol% TiC powder & 46.1 vol% Al_2O_3. TiC powder is added to provide sufficient electrical conductivity (ρ=.009Ωcm). Ceramic composite (AlSiTi) is fabricated by hot pressing at 1700-1800°C in inert atmosphere. After hot pressing (AlSiTi) the composite ceramics achieve a density of approximately 99% [2].

The main objective of present work is to experimentally investigate the grindability aspects of such composite ceramic (AlSiTi). The effects of various process parameters on the grinding forces, specific grinding energy, and surface roughness have been analyzed and the extent of subsurface damages have been studied in a scanning electron microscope (SEM) to obtain an overall view of the grindability aspects of this composite ceramic (AlSiTi).

II. DESIGN OF EXPERIMENT

Experiments are planned by using Taguchi method. Taguchi method involves using orthogonal arrays to organize the parameters affecting the process and the levels at which they should vary. Taguchi recommends the use of the signal-to-noise (S/N) ratios, which are log functions of desired output, and serve as objective functions for optimization, help in data analysis and prediction of optimum results [3].

The three grinding process parameters are selected for surface grinding of the ceramic composite and for each parameter four different levels are chosen. The grinding parameters were wheel speed (V_c), table speed (V_w), and depth of cut (a). Table 1 shows the factor and the levels for the grinding experiments. According to the Taguchi design of experiments sixteen number of experiments are required to conduct the grindibility study of the composite ceramic (AlSiTi) under given factors and their level combination.

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TABLE I. FACTOR AND LEVEL SELECTED FOR THE STUDY

Levels → / Factor ↓	1	2	3	4
Wheel Speed, V_c (m/s)	15(SI)	20(S2)	25(S3)	30(S3)
Table feed, V_w (m/min)	3(T1)	5(T2)	7(T3)	9(T4)
Depth of cut, a (μm)	5(D1)	15(D2)	25(D3)	35(D4)

A. EXPERIMENTAL SET UP

Figure 1. Photographic view of the Experimental Set-up.

The experiments were conducted using a 2 axis CHEVALIER CNC surface grinder. Experimental set up for grinding is shown in Fig. 1. Grinding wheel used for the experimentation is a metal bonded diamond wheel with an average grit size of 91μm. The wheel has diameter of 350mm and width of 25mm. The work material used for this investigation is ceramic composite (AlSiTi) with the dimensions of 20 x 20 x 5 mm^3.

B. MEASUREMENT SYSTEM

The dynamometer used for the measurement of forces is a 3-axis piezoelectric Kistler 9257A dynamometer. The surface finish is a direct process result and was measured by a Taylor Hobson surface tester. The tangential forces are used for the calculation of specific grinding energy requirement, U_g using the below formula given by Malkin [4].

$$U_g = \frac{60 F_t V_c}{V_w a b} \text{ J/mm}^3 \qquad (1)$$

Where F_t = Tangential force in Newtons.
V_c = Grinding wheel speed in m/s.
V_w = Table feed/work speed in m/min
a = Depth of cut in μm.
b = width of workpiece in mm.

IV. RESULT AND DISCUSSION

A. ANALYSIS BY USING MEAN VALUES

Mean response is helpful in assessing the trend of the quality characteristic with respect to the variation of factors under study. Mean response is the average of quality characteristic for each parameter at different levels. The level average responses based upon the experimental data, are shown from figure 2 to figure 4.

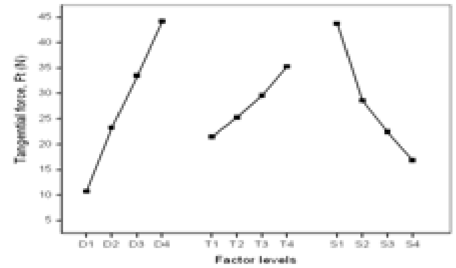

Figure 2(a). Level average response graph for Tangential Force.

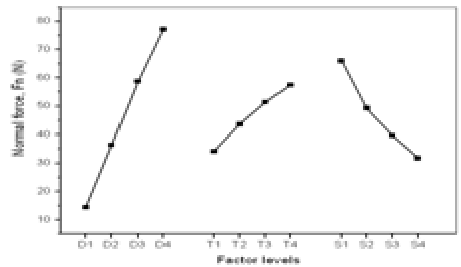

Figure 2(b). Level average response graph for Normal Force.

The forces play an important role in grinding process since it is an important quantitative indicator to characterize the mode of material removal especially in ceramics grinding. The trend of tangential force and normal force with respect to the process parameters like grinding velocity, depth of cut and table speed are plotted in level average response graph.

From Fig. 2(a) and (b) it has been observed that the tangential and normal grinding forces increase with the increase in the depth of cut and table feed. This increase in grinding forces is expected because of increased chip thickness or chip load at higher depth of cut while tangential force and normal force decreases with increase in wheel speed. The reason for such variation is that as wheel speed increases a decrement in magnitude of the average chip thickness results. Average chip thickness equation is derived from the equation of maximum chip thickness given by Agarwal and Rao [5] in their experimental study. Average chip thickness:

$$t_a = \left(\frac{2 * V_w}{m * V_c}\right)\sqrt{\frac{a}{D}} \qquad (2)$$

The specific grinding energy, U_g is defined as the amount of energy required to remove unit volume of material from the workpiece. The trend of specific grinding energy with respect to the process parameters like grinding velocity, depth of cut and table speed are plotted in level average response graph (Fig. 3). It is clear from the Fig. 3, that at lower depth of cut the specific energy is higher and the possible reason

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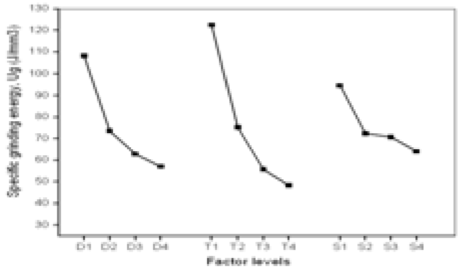

Figure 3. Level average response graph for specific grinding energy.

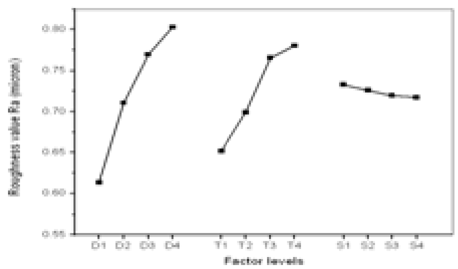

Figure 4. Level average response graph for Roughness value.

for such high specific energy requirement is that at lower depth of cut the effective grit rake becomes more negative, which leads to higher tangential force requirements. Also the rubbing and ploughing effects at lower depth of cut predominate and they consequently increase the specific energy requirement.

The surface roughness graph obtained from the ground surfaces with respect to depth of cut, table feed and wheel speed is shown in Fig. 4.From Fig. 4 it is observed that surface roughness has increased with increase in depth of cut and table feed. This increase may be due to increase in average chip thickness which has occurred due to the increase in depth of cut and table feed.

B. SEM Study Of Ground Sub Surface

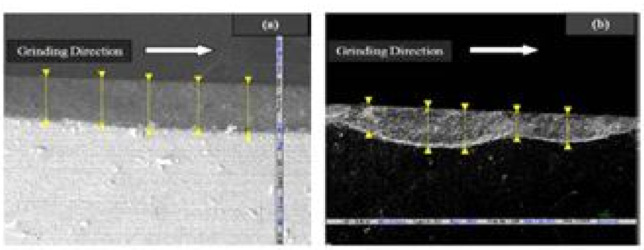

Figure 5. SEM micrographs showing subsurface damage of ground ceramic composite (AlSiTi) under: (a) V_c = 15m/min, V_w = 9m/min, a = 35μm. (b) V_c = 15m/min, V_w = 7m/min, a = 25μm

SEM views of the subsurface damage of the ground ceramic composite AlSiTi specimen under 200X magnification are shown in Fig. 5.

The SEM photographs were taken at that particular combination of parameters where the force values were found to be the highest. It is clear from SEM views of ground composite ceramics (AlSiTi) specimen, that the depth of damage in Fig. 5(b) has been found to be less as compared to Fig 5(a). The possible reason for this is that the force value obtained for the process parameters given in Fig. 5(b) has been found to be much less for the process parametric values given in Fig. 5(a). It is also noted from literature [5] that higher grinding forces normally lead to higher depth of damage.

CONCLUSION

This experimental study investigates grindability aspects of composite ceramics (AlSiTi). Taguchi method of experimental design has been used for the analysis of various factors influencing the quality characteristics. It is observed from the SEM views that the extents of the subsurface damages are quite significant.

This may be due to the high grinding forces and high specific grinding energy requirement. So to improve the grindability characteristics of this type of composite ceramic suitable coolants may possibly help in reduction of the grinding forces and the specific grinding energy requirement. Such reduction in the grinding forces and the specific energy requirement may lead to the reduction in the grinding induced damages.

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